Understanding Synthesizers

by Gordon West

How many remember the days of crystal scanners? Although crystal scanners are still manufactured for limited frequency reception, synthesized scanner sets have the lion's share of the market. In fact, synthesizers are so cost effective that almost every type of radio set has gone from crystal to synthesized. Marine, aircraft, business, citizens band, police, and

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even shortwave radios have switched almost exclusively from crystal and VFO tuning to synthesized tuning. Except in cases where only one or two channels are required, the synthesizer is far more cost effective than VFO and crystal tuning.

"Synthesizing" frequencies for multi-channel and multi-band reception is accomplished by an ingenious electronic system called "phase-locked-loop" (abbreviated PLL). Bearcat scanners were the very first with PLL synthesis with the introduction of the Bearcat 101 scanning receiver in 1975. The basic concept of PLL systems has been known since the early 1930s; however, because of the cost and complexity of non-integrated components, the original application of PLL was limited to extremely expensive receivers and frequency counters.

The advent of the large scale integrated circuit (LSI) made PLL synthesis a natural for scanners.

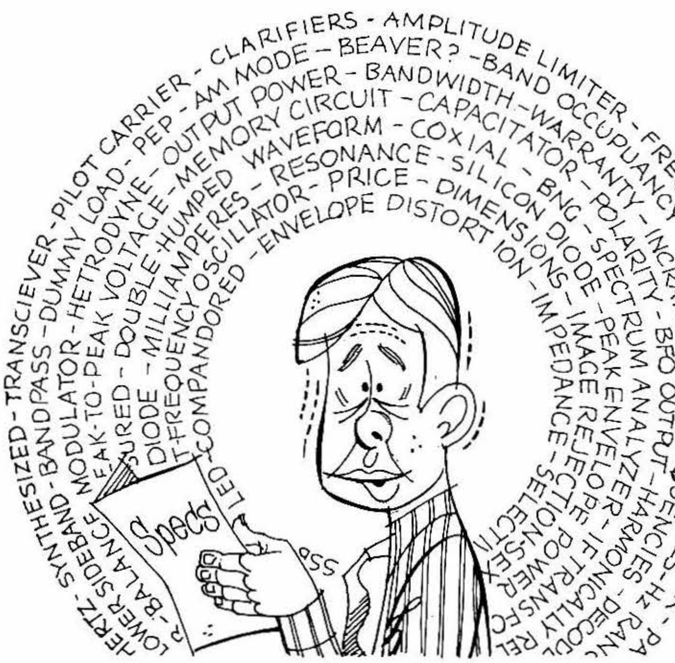
EXPLORING PLL: A phase-locked-loop system contains four basic circuits:

The phase comparator.
The low pass filter.
The DC amplifier.
The voltage controlled oscillator (VCO).

An input signal is first introduced to the phase comparator stage. Simultaneously, the phase comparator is also being fed a voltage from the VCO output. These two signals are mixed and will produce a phase difference that will result in an error voltage. The phase comparator output is filtered, amplified by the DC amplifier, and applied as a control voltage to the VCO.

The control voltage, or error voltage, is used to slightly shift the VCO frequency in the direction that reduces the phase difference between the input signal and the VCO output. This "corrective feedback" circuit will automatically synchronize and lock the input signal and will track only microseconds for this entire complex circuit to "lock in" on a signal. If the signal should drift slightly, the circuits will automatically track it.

The actual range of frequencies over which the PLL circuit will maintain "lock" with an input signal is defined as the "lock range" of the system. Most scanner PLL systems will hold onto any type of varying signal so that reception always remains clear with no noticeable drift.



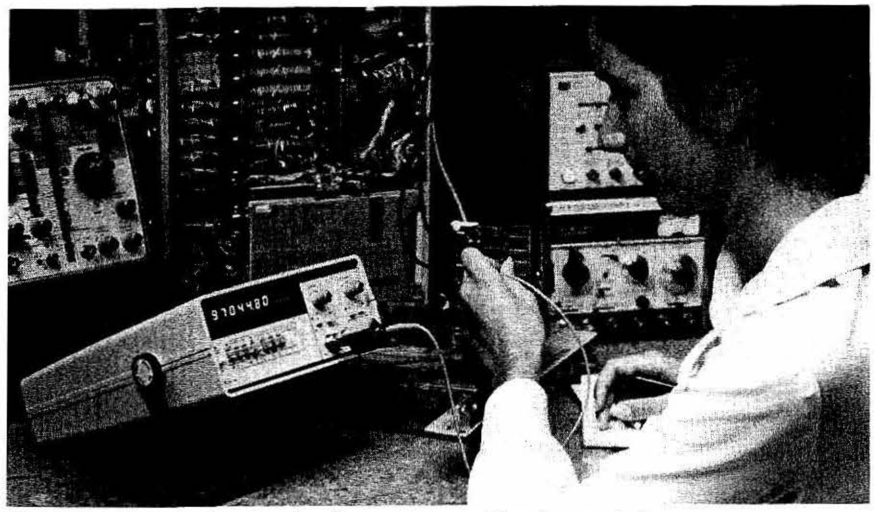
The PLL section of your scanner is fed signals from a "variable counter" network integrated circuit that is tied into the front panel keyboard. The principle of a multi-channel frequency synthesizer is an ideal application of the phase-locked-loop in that many precise frequencies for your scanner may be generated with only one reference frequency. This might allow a scanner to tune five different frequency bands in predetermined steps with a minimum number of components beyond the basic PLL digital frequency synthesizer.

With a programmable counter tied into the scanner keyboard, the operation of a programmable scanner in relationship to the PLL circuit is as follows:

$$Vc = Kp \frac{(\text{ØREF} - \text{ØVCO})}{N}$$

where N is the number programmed into the variable counter.

The range of allowable numbers in N determines the number of finite control voltages, which in turn specify the number of controlled scanner frequencies obtainable. Also, each one of these



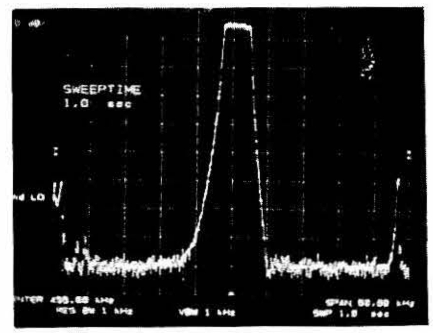
Frequency counter to check master synthesis crystal.

output frequencies, once phase-locked, will be phase coherent with the reference frequency and thus have the same stability as the reference frequency. (The reference frequency must be equal to the VCO frequency divided by the counter divide ratio (N).) That is, the VCO frequency must be the divide ratio times the reference frequency.

Proprietary large scale integrated circuits (LSI) are used by a scanner manufacturer to facilitate programming in their scanner receivers. Early scanners required binary counter selections. In order to store a certain frequency, the user would look up the frequency and then set the binary counters (about 16 switches) to obtain that particular frequency digitally. The frequency was then entered into the memory of the scanner. Newer techniques involving LSI circuits now make programming a snap. There is no longer a need to look up the binary equivalent to the frequency you wish. Simply keyboard enter the exact frequency in MHz, push the memory button, and automatically the scanner does all the work in less than a millisecond. A single precision reference crystal controls the reference oscillator for precise frequency stability. Solid state "counter" chips divide the crystal up into millions of parts that may be used for precise frequency selection.

AM AIRCRAFT COVERAGE. The PLL section of your scanner may also be used for AM signal detection. As you recall, the aircraft band is almost entirely made up of AM double sideband transmissions. The PLL may be used as a coherent detector for demodulating AM signals. The PLL locks on the carrier of the AM signal and produces a reference signal at the output of the VCO. The VCO has the same frequency as the AM carrier, but no amplitude modulation. Then, by multiplying this coherent reference signal with the modulated input signal, and low-pass filtering the output of the mulitplier, one may obtain the demodulated AM aircraft signal information on the scanner. The PLL AM detector system also exhibits a high degree of selectivity for accurate frequency tracking. It also offers a higher degree of noise immunity than conventional peak-detector-type AM demodulators.

SCANNING AND SEARCHING. Proprietary patents from Electra Company allow the receiver to rapidly sample (scan) certain groups of frequencies, banks of frequencies, individually programmed frequencies, and even search complete bands of frequencies for activity. Feedback voltage from the squelch circuit immediately locks the scanning receiver onto any channel with activity. When the signal disappears, a capacitor discharges and then releases the synthesizer to resume scanning or searching. The amount of delay time after the signal disappears is usually user programmable via the keyboard.



AM reception from PLL circuit.

BAND LIMITS. A PLL synthesizer circuit has virtually no limit on how high or low it may operate . The basic receiver design is what determines which group of frequencies may be monitored. The higher the frequency, the greater the stability necessary for frequency scanning.

Why not 900 MHz? Receiver designs simply won't allow a 900 MHz bank of frequencies to be easily combined with a receiver that tunes from 30 MHz through 400 MHz in five bands. PLL synthesis could certainly handle the job—it's just that receiver designs at 900 MHz are completely different than a 400 MHz and below. Costly strip-line circuitry is used at these microwave frequencies. Conventional printed circuit board design is used at frequencies below 450 MHz. The cost of developing a receiver that would cover low, high, very high, ultra high, and 900 MHz microwave frequencies would generally be prohibitive.

There is also no formal band plan for the entire country at 900 MHz as of yet. The Federal Communications Commission is still
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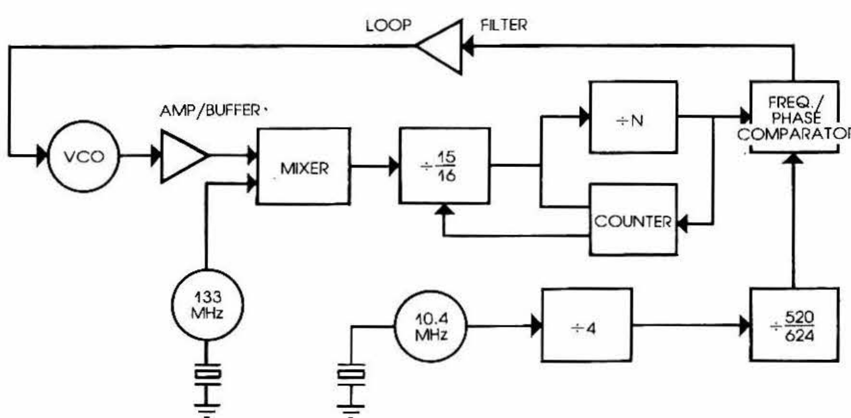

Synthesizer circuit of a typical modern scanner.

Another country which has experienced a great deal of internal conflict recently is El Salvador. The government station, Radio Nacional, maintains an irregular schedule on 9553 kHz (variable). This station has not been heard at all in recent months, but is expected to be back on the air soon, possibly on a different frequency.

A clandestine station, Radio Venceremos, is the voice of many of the guerillas who are fighting the current government here. Radio Venceremos has been heard often in the 6200-7000 kHz area with speeches, revolutionary music, and sound effects such as machine gun fire. This clandestine broadcaster is reported to be in El Salvador.

Elsewhere in the region, conflict between government and rebel forces has not reached the level that it has in Nicaragua and El Salvador.

There are a number of small, interesting stations in Costa Rica, Guatemala, and Honduras (see accompanying list for stations that are active). Station counters may want to log these stations now, before the winds of change come over these countries.

Belize, though technically not part of Central America, also boasts a small shortwave broadcaster. Radio Belize is difficult to hear, but offers unique news and music programs. Panama, often considered to be part of Central America, is the only country in Latin America without a shortwave station. Further changes, political and otherwise, are inevitable, and everything will be well documented on the shortwave bands.

Central American Shortwave Stations

Country	Station—Frequency	Time (GMT)
BELIZE	R. Belize—3285*	0200
COSTA RICA	R. Reloj—4832	0300
	Faro del Caribe—5055*	0300
	R. Rumbo—6078	0900
EL SALVADOR	R. Nacional—9553	0100
GUATEMALA	R. Cultural—3300	0300
	R. Maya—3325	1100
	L.V. de Nahuala—3360	1100
	R. Chortis—3380	0200
	R. Mam—4825	0100
	R. Tezulutan—4835	0100
	R. Nacional—6180*	1100
HONDURAS	R. Luz y Vida—3250	0200
	R. Juticalpa—4780	1100
	L.V. Evangelica—4820*	0200
	R. Lux—4890	0100
	L.V. de Mosquitia—4910	0200
NICARAGUA	L.V. de Nicaragua—5950*	0200
	R. Zinica—6120	1100

*-Presents regular or occasional broadcasts in English.

Understanding Synthesizers
(Continued from page 11)

assigning blocks of frequencies in this area, and it would be premature to develop equipment until the band plan is formally agreed upon. Although a crystal type receiver at 900 MHz has been previewed, it will still be a few more years before we see low cost PLL synthesis at this range.

SUMMARY. Scanner radios have defied the laws of "more complex=more expensive." Scanners are one of the few types of radio receivers that have actually been dropping in price as the technology has been increasing.

Proprietary LSI designs help keep cost low but preformance high when developing scanner receivers that synthesize frequencies. Scanner manufacturers will continue to develop new techniques to make programming and listening a breeze for users who may have no knowledge on what goes on inside their sets.